EXHIBIT 33

February 21, 2007

Dr. Leonard F. Konikow
Research Hydrologist
U.S. Department of the Interior
Geological Survey
12201 Sunrise Valley Drive
Mail Stop 431
Reston, Virginia 20192

Dear Dr. Konikow:

On behalf of the Agency for Toxic Substances and Disease Registry (ATSDR), I would like to thank you for reviewing the following report

Simulation of Fate and Transport of Tetrachloroethylene (PCE) in Ground Water at Tarawa Terrace and Vicinity, Marine Corps Base Camp Lejeune, North Carolina, **by Robert E. Faye**

Enclosed are the author's responses to your review comments.

Please accept my thanks for assisting us in ensuring the highest caliber for our scientific investigations. Should you have any questions, please feel free to call me at telephone (404) 498-0415. I can also be contacted by electronic mail at: mmaslia@cdc.gov.

Sincerely yours,

Morris L. Maslia, P.E., DEE, D.WRE
Research Environmental Engineer

Enclosure:
Response to review comments

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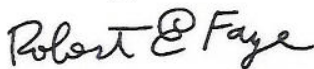Email: refaye@alltel.net

February 14, 2007

Ms. Naida Gavrelis
Eastern Research Group
110 Hartwell Avenue
Lexington, MA 02421-3136

Dear Ms. Gavrelis:

Responses to review comments by Dr. Leonard F. Konikow regarding the report "Analyses of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Potable Water at Tarawa Terrace and Vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina: Historical Reconstruction and Present-day Conditions, Chapter F: Simulation of the fate and transport of tetrachloroethylene (PCE)" are listed below in the order presented by the reviewer by letter dated July 27, 2006. The reviewer listed 5 items of major concern and then numerous page-by-page comments. The major concerns are addressed directly below followed by the page-by-page comments.

The authors wish to thank Dr. Konikow for a thorough and knowledgeable review and we are greatly appreciative of his efforts.

Sincerely,

Robert E Faye

Robert E. Faye, P. E.

Major Concerns

1. The lumping of two aquifers and one confining unit into the surficial model layer 1:

The Tarawa Terrace aquifer and confining unit and the UpperCastle Hayne aquifer-River Bend unit are combined into model layer 1. Although the Tarawa Terrace confining unit in the vicinity of ABC One-Hour Cleaners and the STT tanks is locally somewhat competent, as evidenced by driller's comments regarding "running sands", the Tarawa Terrace aquifer and confining unit generally are thin and discontinuous in the northern part of Tarawa Terrace and vicinity. In the southern part of Tarawa Terrace, east and in the vicinity of the Tarawa Terrace shopping center, the Tarawa Terrace confining unit is difficult to distinguish, even in detailed boring logs, and the Tarawa Terrace aquifer and Upper Castle Hayne aquifer-River Bend unit appear to be vertically continuous.

Numerous water-level data in the vicinity of ABC One-Hour Cleaners, northern Tarawa Terrace, and in the southern part of Tarawa Terrace near the Tarawa Terrace shopping center indicate conclusively that (1) vertical hydraulic gradients between the Tarawa Terrace aquifer and the Upper Castle Hayne aquifer-River Bend Unit are small and inconsequential. In other words, water levels measured to a hundredth of a foot in paired observation wells open respectively to the two aquifers were the same or nearly the same during several measurement cycles; and (2) these same water-level data indicate that the water table generally occurs near the base of the Tarawa Terrace confining unit/top of the Upper Castle aquifer-River Bend unit. During or immediately following periods of significant and prolonged rainfall, the water table may temporarily reside at the base of the Tarawa Terrace aquifer. Thus the Tarawa Terrace aquifer and confining unit probably are only partially saturated much of the time. Given these field observations and lines of evidence, the authors believe that combining the 3 defined hydrogeologic units into a single model layer was hydrologically and hydraulically appropriate.

2. The use of a finite-difference method to solve the governing transport equation (which causes substantial numerical dispersion, especially if time steps are too large):

First of all the reviewer probably has no idea whether or not using a code based on finite-difference methods caused "substantial" or insubstantial numerical dispersion during solution of the Tarawa Terrace fate and transport model. Certainly, some numerical dispersion occurred; however, the degree or effects of this dispersion are unknown and, to the best of our knowledge, cannot be accurately determined. Secondly, at the beginning of the fate and transport modeling process, linked output from the flow model was applied to several transport codes, including MOC3D. All of these codes, with the exception of MT3DMS, either failed to converge or created unstable (oscillating) solutions. Thirdly, the MT3DMS model was designed with a Peclet number ($\Delta x/\alpha_L$) equal to 2.0 (Δx = 50 feet, α_L = 25 feet). A Peclet number of 2 or less generally minimizes numerical dispersion for a particular solution. Consider, as well, the Courant number ($v\Delta t/\Delta x$), which affects the occurrence of oscillations arising from the discrete approximation of the time derivative. The Courant number should equal one or less for all cells

in all layers during all stress periods in order to control numerical oscillations. Simulated flow velocities (v) ranged between 0.01 and 1.0 feet per day at all cells in all layers except in the immediate vicinity of pumping wells, where velocities were as high as 8 feet per day. At all cells, $\Delta x = 50$ feet and $\Delta t = 28, 29, 30$ or 31 days. Thus, out of a total of approximately 27,000 cells in each model layer, the Courant number was less than one at all but a few dozen cells in the immediate vicinity of pumping wells. With respect to the calibrated flow and fate and transport models, numerical oscillations did not occur in any cell in any layer during any stress period. Furthermore, the MT3DMS code is well-documented and has been available in the public domain for about a decade. The code is well-recognized as a stable and numerically accurate solution platform.

3. The reliability of the estimate of the biodegradation rate constant based on the assumption that concentration declines observed at one location over a period of several years can be explained solely by biodegradation:

The authors never claimed that the biodegradation rate computed using field data was reliable or the sole reason for the observed decline in PCE concentration. Rather the computed rate was presented as an approximate value useful to begin model calibration. Well TT-26 is located on a direct migration/advective pathway from the PCE source at ABC One-Hour Cleaners (Figures 2, 5). To the extent that migration of PCE mass toward and away from supply well TT-26 occurred at about equal rates during 1985 to 1991, the computed degradation rate of 0.00053 per day approximates a long-term average degradation rate. On the other hand, if a significant quantity of the PCE degraded in the vicinity of supply well TT-26 was replaced by advection, then the degradation rate computed using Equation (3) is probably a minimum rate. The report does not state or indicate that the decline in PCE mass at supply well TT-23 is due entirely to biodegradation. Rather, the report indicates that the computed first-order degradation rate is an estimate used as a basis to begin model calibration.

4. The exclusion of concentration data collected in monitoring wells from the calibration basis:

Monitor well concentration data were excluded from consideration when calibrating the fate and transport model because the concentration data from monitor wells did not represent a complete or uniform mixing of solute within an intersticial volume comparable to the intersticial volume of a model cell. In other words, the scales of measurement or observation between monitor wells and model cell dimensions in terms of the volume of aquifer sampled were different by orders of magnitude. Analytical results from water-quality samples obtained from monitor wells are affected by local aquifer heterogeneities that could not be measured or accounted for when constructing the Tarawa Terrace flow and fate and transport models. On the other hand, samples obtained from operating supply wells are composite samples obtained from a large volume of the contributing aquifer or aquifers and reflect well-mixed or average conditions within the water-bearing units. Thus samples collected at supply wells conform to a considerable degree to the assumptions and limitations that apply to simulated results from the Tarawa Terrace fate and transport model.

Consider a typical monitor well, such as well S3 and located near well TT-26. Well S3 is 39.5 feet deep, well diameter is 4 inches, and the well is screened from 19.5 to 39.5 feet. The screen is open to the base of the Tarawa Terrace aquifer and the upper part of the Upper Castle Hayne aquifer-River Bend unit. The observed depth to water ranges between about 20 and 22 feet. At a depth to water of 20 feet, the casing water volume is about 28 cubic feet. This casing volume was removed 3 to 5 times prior to obtaining a water sample for water-quality analysis. At an effective porosity of 0.2, a maximum of about 150 cubic feet of aquifer volume was sampled. In addition, this aquifer is highly heterogeneous locally and consists of silty sand and thin, discontinuous beds of clay and silt that influence the distribution of solute at a scale of inches or several feet. Such heterogeneity causes variability in transport processes, particularly advective and dispersion processes that could not be simulated using the cell and layering resolution of the fate and transport model. Hydrocone data collected in the vicinity of well S3 reflect this small-scale variability. For example, at site HC-9 at a depth of 31 feet the observed PCE concentration was 176 µg/L; at almost the same site at the same time at a depth of 36.5 feet the PCE concentration was 6.3 µg/L. Site HC-9 was located about 300 feet east of wells S3 and TT-26. At site HC-20, near wells S3 and TT-26, the PCE concentration at a depth of 34 feet was 500 µg/L; at almost the same time at a depth of 41 feet the PCE concentration was 196 µg/L. PCE concentrations determined from analyses of 2 water samples collected from well S3 were 380 and 5,400 µg/L. The hydrocone samples were collected during December 1991. Water-quality samples from well S3 were collected during April 1992 (5,400 µg/L) and September 1993 (380 µg/L). Such variability with depth and time could not be replicated using the layer geometry, cell resolution and constant loading rates applied to the Tarawa Terrace fate and transport model.

Consider next a model cell representing model layer 1 and containing well S3. The cell represents an area of 2500 square feet and an average thickness of about 40 feet, or a volume of 100,000 cubic feet. Consider also that during simulation, PCE mass available at this cell is distributed uniformly and instantaneously throughout the available intersticial volume of the cell at the end of every stress period. In other words, the simulated PCE concentration is everywhere equal within a given model cell during an individual stress period. Compare this condition to the highly variable distribution of PCE with depth noted previously at sites HC-9 and HC-20. Obviously, PCE is not distributed uniformly throughout the "real world" aquifer and PCE concentrations change by orders of magnitude over short intervals of depth. Similar or comparable variations in PCE concentration likely occurred across the screened interval of monitor well S3 and the open intervals of other monitor wells. Although mixing occurs during the sampling process, PCE concentrations obtained from well S3 reflect variability caused by local heterogeneity and relate to only a tiny percentage of the volume of a model cell. Only by the most unique and rarest of coincidences could one expect highly variable PCE concentrations within an aquifer volume of 150 cubic feet to equal or be comparable to a corresponding simulated concentration uniformly distributed throughout an aquifer volume of 100,000 cubic feet in the same area.

5. The use of a much larger mass loading rate than apparently was indicated by the field data in order to improve the model calibration:

First of all please note that field data did not indicate a mass loading rate. The computations of PCE mass in the saturated and unsaturated zones described in the report were the result of a highly interpretive, somewhat subjective calculation using field data. With respect to the calculation of PCE mass in solution, the field data were sparse and limited to only 2 depth intervals. Secondly, the report explicitly states that the calculated mass loading rate is a *minimum* rate. Three lines of evidence were provided to support this conclusion: (1) the quantity of PCE removed from the aquifers at Tarawa Terrace supply wells during 1953 to 1985 is unknown, (2) the mass of PCE degraded to TCE during 1953 to 1985 was probably large and was not accounted for by the computation of PCE mass, and (3) similarly, the mass of PCE sorbed onto the porous media during 1953 to 1985 was also probably substantial and was not accounted for by the computation of PCE mass. These are reasonable and compelling lines of evidence to conclude that the calculated average PCE mass loading rate described in the report is a *minimum* rate; however, they were apparently ignored by the reviewer. An additional line of evidence is indicated by the discussion in #4 above wherein a high degree of variability with depth is described regarding PCE concentrations. At hydrocone sampling sites, PCE concentrations were determined at two depth intervals, frequently separated by 10 feet or more. That substantial PCE mass occurred within the zone of separation and was not accounted for when calculating the average PCE concentration between "shells" is highly probable.

The reviewer elaborates further on this concern on page 4 of his comments by introducing the issue of total versus effective porosity. The reviewer apparently believes that ground water containing PCE mass saturates the total pore space, not just the pore volume represented by connected interstices. Over time, because of the migration of PCE in solution along concentration gradients, some mass will occur within disconnected interstices; however, by definition, this mass is trapped and cannot move to wells or hydrocones to be sampled. The computation of PCE mass was obviously based on solute that was transported within the ground-water flow regime to wells or other sampling devices and thus was related to effective rather than total porosity. Effective porosity represents the volume of connected interstices that permits and facilitates the flow of ground water through a porous media. Total porosity represents the total volume of interstices, those connected and transmitting ground water and those disconnected or otherwise isolated from the ground-water flow regime. Effective porosity is always less than total porosity. By definition, ground water, including contaminated ground water, flows only through connected interstices. Some exchange of PCE mass from connected interstices to disconnected or isolated pore space possibly occurs along concentration gradients. However, the greatest concentration, by far, of PCE mass in solution is transmitted through and resides within connected interstices, particularly as flow path distance increases away from the source area and toward supply wells. Accordingly, the authors believe that using effective porosity to calculate residual PCE mass as shown in Table 11 was entirely appropriate and reasonable.

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Page-by-Page Comments

p. 17: Agree. Report corrected.

p. 22: The period of time described in the Scope of Study (January 1952 to March 1987) is correct. The Scope specifically refers to the simulation of PCE concentrations at Tarawa Terrace supply wells "for their entire period of operation, January 1952 through March 1987". For simulation purposes, Tarawa Terrace supply wells began pumping in January 1952. Pumping at supply wells was terminated in March 1987.

Fig. 1: Agree. All figures and tables and tables in the report will be published according to USGS standards.

Fig. 8: Agree. A new base for Figure 8 and similar figures will include just the contaminated area. Contours and contour fills will be well-defined and easy to read.

p. 30: Agree. The abbreviation "CLP" probably stands for "Clinical Laboratory Program", an organization/process that inspects state and Federal laboratories for purposes of certification. This abbreviation was never defined in the ABC One-Hour Cleaners OU1 and OU2 reports. We are still trying to confirm the true definition of the abbreviation as reported and will include same in the final draft of the report if we are successful.

Tables 9 and 10: Disagree. Borehole depth is the total depth of the borehole drilled prior to constructing a well. The well depth is the depth of the completed well. These terms convey pretty basic information familiar to most ground-water hydrologists and footnotes explaining same are not necessary.

p. 32 and Fig. 11: Agree. Comparing the thickness of the "Castle Hayne aquifer" shown on Figure 11 of Cardinell and others (1993) to the thickness of the Castle Hayne Formation of this study (also Figure 11) is somewhat of an "apples to oranges" comparison. Cardinell and others included most or all of the Tarawa Terrace aquifer of this study and the Upper Castle Hayne aquifer-River Bend unit of this study in their "Castle Hayne aquifer". These units are not included in the Castle Hayne Formation as defined for this study. In addition, the top of the Beaufort confining unit, which defines the base of the "Castle Hayne aquifer" of Cardinell and others (1993) and the Castle Hayne Formation of this study, is placed significantly lower in the Tarawa Terrace area by Cardinell and others (1993) than interpretations of borehole and lithologic data used for this study would suggest. The altitudes reported at the top of the Beaufort confining unit by Cardinell and others (1993 Table 3) are far below the bottom hole depth of any borehole geophysical or lithologic log available in the Tarawa Terrace area and were estimates, probably based on interpretations of surface resistivity or seismic surveys. Considerable uncertainty is attached to these data as acknowledged by Cardinell and others (1993) in their heading notes attached to their Table 3 and by questioning the depth of the top of the Beaufort confining unit shown in sections on their Plate 1. The combined effect of these

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differences would add an additional 50 to 150 feet of thickness to the contours shown on Figure 11 of this study. Of the hydrogeologic units used to define the layer geometry assigned to the Tarawa Terrace flow and fate and transport models these differences would affect only the thickness of the lower Castle Hayne aquifer, the lowermost hydrogeologic unit and layer 7 of the models. The differences described herein are also discussed in Chapter B of this study, which describes the hydrogeologic framework in the Tarawa Terrace area.

p. 40: Agree. Comprehensive water-level data were available only after contaminated ground water was discovered in the Tarawa Terrace area and various entities began remedial investigations. Consequently, only simulated potentiometric maps of pumping conditions are available. Simulated potentiometric surface maps showing pumping conditions are compared to the conceptual model in a later section of the report.

p. 42: Disagree. The reviewer appears to believe that when the report states that only one transport process was observed (biodegradation), the authors were somehow mislead and actually should have stated that several other processes (dispersion and diffusion) were also observed. Dispersion and diffusion were not observed.

p. 44, top: Agree. One stress period represented one month with the appropriate number of days assigned to the stress period as Δt. No time steps were used within stress periods. This information will be added to the report.

p. 44: Agree. The reviewer's concerns were addressed in item #1 of Major Concerns. The reviewer was possibly mislead by the maximum thickness of the Tarawa Terrace aquifer listed in Table 1 (60 feet). The maximum thickness mistakenly refers to locations southeast of Tarawa Terrace between Northeast and Wallace Creeks included in the framework report (Chapter B of this study). The maximum thickness of the Tarawa Terrace aquifer at Tarawa Terrace is about 30 feet and is 20 feet or less near the source area for PCE contamination. The thickness values listed on Table 1 were corrected.

The water table at the source area and vicinity occurs temporarily at the base of the Tarawa Terrace aquifer during periods of significant and prolonged rainfall but generally occurs at or near the top of the Upper Castle Hayne aquifer-River Bend unit. In addition the Tarawa Terrace confining unit in this area is thin and discontinuous and in the southern part of Tarawa Terrace is missing altogether. The reviewer's comment that simulated mass loading occurs directly to the River Bend unit is correct and conforms to known hydrologic conditions in the study area. Keep in mind that the scope of this study did not include simulation of flow or contaminant through the unsaturated zone. Thus, transit time through the unsaturated zone to the water table was not accounted for. With infrequent exceptions as explained previously, the porous media that overlies the River Bend unit is unsaturated. The framework report (Chapter B of this study) includes maps showing thickness and altitude at the top of the Tarawa Terrace confining unit. Additional qualitative descriptions of the Tarawa Terrace confining unit were added to the framework report.

p. 44-45 and fig. 12: Disagree. The report states specifically that the western boundary generally conforms to the drainage divide between Frenchman and Scales Creeks. This includes the boundary segment of concern to the reviewer. Additional qualification has been added to the report.

p. 46, lines 5-10: Agree. The terms dispersion and coefficient were used incorrectly in the report where dispersivity should have been used. The text has been corrected.

p. 51: Agree. Sorption processes are unknown for this study. Consequently a statement regarding such processes that is definitive cannot be scientifically defended. Consequently, "a very weak justification was used, assuming it (linear isotherm) is the appropriate model." The parentheses are the authors.

p. 52 and 53: Agree. Unit weight and bulk density are synonymous in English units. Bulk density is the term used in the MT3DMS documentation and should be consistently used in the report. The report text has been corrected.

General comment: Most units used in this report are as reported. Occasionally, during computations such as the calculation of PCE mass, units are converted from English to metric and vice versa because the data used were originally reported in English or metric units and the results had to be presented in useful terms such as gallons or cubic feet. The rate of contaminant loading assigned to the model is reported in grams/day. Concentrations were originally simulated in grams/cubic foot. Feet were used in order to be consistent with flow model data linked to the fate and transport model. Grams were used in order to compare simulated results to observed results which are always reported in milligrams or micrograms per liter.

p. 53, para 1, last line: Agree. The calibrated retardation factor should have been reported as 3.7. The text has been corrected.

p. 56: Agree. The report should read equation 3. The text has been corrected.

p. 56 and 57: A "shell" represents a grouping of spatial data characterized by common attributes. To the best of the authors' knowledge, the term is commonly used to describe overlying GIS coverages. The term was appropriately used in the report.

Table 11: Disagree. In Table 11, the numbers are shown to the significant figures listed simply to allow the reader to check and reproduce, if necessary, the computation of PCE mass. The real test of the "accuracy and precision" intended by the authors is the final results, which are reported to 2 significant figures.

Table 11, p. 137: Agree. The units were reported incorrectly and should have been grams per liter instead of milligrams per liter. The results are reported correctly in the text.

p. 56 and 57 and Table 11: Disagree. The text clearly explains that the computations shown in

Table 11 are performed on the volume of material computed between the upper and lower shells. The volume-weighted concentration is clearly defined as the total of sub-area weighted concentrations divided by the total of all subareas. Perhaps "volume-weighted" is a confusing term. The authors' intention in using this term was to indicate the average concentration within the volume delimited by the upper and lower shells. An attempt will be made to create a less confusing term. The thickness of porous media between the upper and lower shells was determined by interpolating the altitudes of sampling depths or the mid-points of screened intervals at specified wells (control points) located within the upper and lower shells. The results of this effort were 2 contour maps that defined the surface area and altitude of each shell. The volume of media between shells was computed by subtracting, in effect, the lower shell contour map from the upper shell contour map using GIS. The correct volume-weighted concentration was 0.0014 grams per liter. The correct concentration was reported in the text. The units on Table 11 have been corrected.

p. 46 to 59 Model input data and initial conditions: Agree. A sentence has been added to the report indicating that initial concentration arrays were assigned as zero grams/cubic foot for all layers.

p. 55 and 56 Biodegradation rate: Disagree. This criticism was previously addressed under Major Concerns, item #3. The reviewer's suggestion to simulate PCE concentrations using a degradation rate of zero and adjust the field data by simulated changes is not accepted. Adjustments to field data using such simulated changes would add additional uncertainty to an already uncertain process.

p. 57 Mass loading: Disagree. This criticism was previously addressed under Major Concerns, item #5.

p. 59 Mass loading: Disagree. See comments under Major Concerns, item #5. The reviewer seems to assign a high degree of accuracy and credibility to the PCE mass computation that is unwarranted. As explained previously, the computation of PCE mass was a highly interpretive and somewhat subjective process frequently based on questionable data. Field data applied to the PCE mass computation were limited both spatially and vertically. The computation was accomplished regardless of data limitations to provide an estimate of a minimum mass loading rate to use to begin model calibration.

The results reported for this study are reasonable within the context of limited and frequently questionable field and operations data. Legal depositions indicate that ABC One-Hour Cleaners replenished their PCE supply at a rate of two or three 55 gallon drums per month. The unit weight of PCE is approximately 100 pounds per cubic foot. Using two drums per month, or 110 gallons of PCE, ABC One-Hour Cleaners replaced about 1470 pounds or about 670,000 grams of PCE monthly. The calibrated mass loading rate applied to the model represents about 36,000 grams of PCE per month or about 5 percent of total usage. Using three drums per month, this percentage drops to 3.6 percent. These percentages represent loss not only to waste water but to filter and still residues which were disposed to the land surface in the immediate vicinity of the

cleaners as well as spills from a 250 gallon PCE storage tank external and adjacent to the cleaners' building. Because PCE is a high-expense item, efficient use of PCE is critical to a profitable dry-cleaning operation. Thus, the calibrated mass-loading rate indirectly reflects a reasonable operational efficiency and PCE loss rate at ABC One-Hour Cleaners. A direct comparison between the mass loading rate applied to the model and total operational losses of PCE at ABC One-Hour Cleaners is not possible because the greatest loss of PCE at the cleaners, far and away, was to volatilization during the various stages of dry cleaning. Consider, as well, that PCE losses to the subsurface from the cleaning operations were originally delivered either to the land surface or to the shallow subsurface and migrated vertically through about 20 feet of unsaturated zone to the water table. Within the unsaturated zone, PCE mass was lost to aerobic degradation and retention. Accordingly, the mass loading rate applied to the MT3DMS model equates, at best, only to a minimum PCE loss rate to the subsurface and is not comparable to a total loss due to operations.

Increases in mass loading rate were accomplished during model calibration by comparing simulated results to PCE concentration data collected at Tarawa Terrace supply wells and at the Tarawa Terrace WTP. These data were available periodically only from 1982 to 1985 and again in 1991.

Whether or not 80 percent of PCE as solute is removed from the subsurface by wells and transport processes, as suggested by the reviewer, is reasonable or unreasonable cannot be resolved independent of model simulations. The hierarchical calibration process and the excellent calibration results at calibration levels 3 and 4 suggest that model simulations are indeed reasonable.

p. 59 Model calibration: Agree. The report text was corrected to remove the reference to iterative adjustments of simulation results. Adjustments to model arrays during calibration were manual, trial and error. The mass loading rate, biodegradation rate constant, and distribution coefficient were selected for adjustment during calibration because initial estimates of these parameters were considered highly uncertain. Literature descriptions of rate constants and distribution coefficients were used as general guides during calibration; however, literature sources were limited and pertinent data specific to the Camp Lejeune area or even North Carolina were not available. Effective porosity and longitudinal dispersivity were not adjusted during calibration as initial estimates of these parameters were considered reasonable. In addition, simulation results are only minimally sensitive to changes in longitudinal dispersivity.

An enhanced description of the approaches and methods of model calibration will be added to the introduction to Model Calibration.

p. 60 Level 3 calibration: Comments in this paragraph seem largely redundant to concerns expressed previously and were addressed herein in the preceding paragraph. The "conceptual" bases for calibration were, secondarily, literature descriptions of rate constants and distribution coefficients and, primarily, comparisons of simulated PCE concentrations to field data. This report does not provide and was never intended to provide (1) a daily log of calibration

activities, (2) a catalog of thoughts and approaches leading to particular parameter adjustments, or (3) descriptions of hypothetical (conceptual implications) what ifs with respect to calibration decisions. A summary description of calibration methods and approaches is provided and is sufficient for the purposes of this report.

p. 60 Level 3 calibration: Agree. The report text has been modified to conform to the reviewer's comments. Simulated concentrations are computed for the last day of each month (stress period) and this concentration is considered representative of average conditions for the entire month.

p. 60 Level 3 calibration: Disagree. The reviewer's concerns are addressed under Major Concerns, Item #4. Monitor well data could be used for model calibration if, instead of a 50 feet per side cell dimension, model cell resolution was about 1 foot per side with respect to monitor wells and about 6 inches per side with respect to hydrocone data. Such resolution is totally impractical given the size of the model domain.

p. 60 next to last line: Agree. The text should have read "6 sides to a cell". This was a poor example used to compare scales of measurement. The example has been removed and the text modified per Item #4 of Major Concerns. The reviewer's comment regarding a 100 foot thickness that was somehow used in a unit conversion shown on Table 11 is incorrect.

Fig. 8: The title for figure 8 should read 1991-1993. The dates listed in Table 5 are correct. Data additional to those listed in Table 5 were used to generate Figure 8, thus the different time intervals.

p. 61, line 1: The calibration standard of one-half order of magnitude was selected somewhat arbitrarily and reflects the confidence level expected of calibrated model results. A literature example of exactly this approach is unknown.

p. 61, line 3: Agree. The text has been modified per Item #2 of Major Concerns.

Table 12: Agree. Table 12 has been modified.

p. 62, line 4: Agree. The report text has been corrected.

p. 62, line 8: The locations of supply wells RW-01, RW-02, and RW-03 are shown in Figure 4 and were located during a well reconnaissance prescribed for ABC One-Hour Cleaners OU1. Well RW-02 was located in a commercial building (furniture store) immediately next to ABC One-Hour Cleaners. Little is known about these wells except their location, estimates of depth and perhaps some additional construction details. Pumpage and operation data were not available. Pumpage was considered insignificant for modeling purposes and pumping was not simulated.

Fig. 14: Most concerns expressed in this paragraph were answered previously. The well location is shown in Figure 4; however, the illustration is too small to read easily. This figure

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and all other illustrations for this report are being redrafted by the USGS, which will completely resolve the reviewer's concerns.

Figs. 14-19: Agree. The final illustrations will include observed concentrations. The reviewer's comments regarding underestimates of peak concentrations are confusing. The authors have no knowledge of field observations of peak contaminant concentrations and only simulated concentrations are shown on Figures 14-19.

Vertical distribution of contaminants: Simulated contaminants were observed above detection levels as deep as model layer 5. Discussions of the vertical distribution of contaminants will be added to the report. The "lower unit" that the reviewer refers to is the Upper Castle Hayne aquifer-Lower unit, layer 3 of the model.

p. 62-64: The authors will consider graphs of pumpage assigned to model supply wells but our immediate thought is what useful or pertinent information will such graphs provide.

p. 64. bottom: The authors believe the report clearly indicates that the time in question is December 1968. Comparisons are made between simulated fate and transport simulations accomplished for December 1960 and December 1968 (Figures 20 and 21). Considerable increases in supply well pumpage directly south of ABC One-Hour Cleaners occurred during this interval and corresponding changes in hydraulic gradients and PCE plume distribution are described. Hydraulic gradients north to south in the vicinity of ABC One-Hour cleaners increased and caused a corresponding increase in flow of uncontaminated water from the general-head boundary located just north of the cleaners. This additional flow from the boundary caused additional dilution of the PCE mass in the source area between December 1960 and December 1968. Simulated flow from the head-dependent boundary during December 1960 was about 47,000 cubic feet per day. Simulated flow from the head-dependent boundary during December 1968 was about 101,000 cubic feet per day. Corresponding flows during December 1975 and December 1984 were relatively constant at about 71,000 cubic feet per day. Note as well that the simulated plume area increased by about a factor of 4 between 1960 and 1984. The dissipation of PCE mass to progressively larger areas over time and the dilution of the mass caused by corresponding increases in head-dependent boundary flow are the major causes of the progressive decrease in simulated PCE concentration in the source area. The authors do not accept the reviewer's suggestion that simulated decreases in source area concentration are the result of numerical error. Additional discussion and qualification of the information shown in Figures 20-29 will be added to the report. The reviewer's several references to 1963 are not understood.

p. 67, item 3: The reviewer is correct that a mass of PCE remained in the unsaturated zone following termination of simulated mass loading after December 1984. However, residual mass loading from the unsaturated zone could not be reasonably estimated with available data. In addition, the residual PCE mass in the unsaturated zone was considered stable and any loading from the unsaturated zone was considered inconsequential compared to the mass of PCE as solute resident in the various aquifers at Tarawa Terrace at that time. Consequently simulated

PCE concentrations at Tarawa Terrace supply wells between January 1985 and March 1987 should be considered conservative estimates. The report text will be modified to reflect these conclusions.

p. 67: Agree. The reviewer's suggestions to add various plots of mass balance components during the entire period of simulation to the report are excellent and will be accomplished for the final report. The simulated reduction in PCE concentration at the source was certainly affected by recharge as well as boundary inflows, sorption, biodegradation, and dispersion. The suggestion to illustrate the PCE distribution during March 1987 is accepted and this illustration will be added to the final report.

The simulated PCE plume following the termination of mass loading and pumping at supply wells continued to expand in size, as expected, and plume concentrations continued to be degraded by recharge, sorption, biodegradation, and dispersion.

p. 68, line 9: Agree. The report text is misleading regarding the information presented in Table 13. The text will be modified to correct this problem.

Figure 30: That simulated results are probably not unique is being addressed by the Tarawa Terrace project by completing Monte Carlo analyses of numerous alternative distributions of hydraulic characteristic arrays and by varying individual pumping schedules at all supply wells to determine maximum and minimum breakthrough times and possible ranges in computed PCE concentrations at the Tarawa Terrace WTP.

The "lumping" of units into model layer 1 and the derivation of the mass-loading rate have been thoroughly addressed. Issues of numerical dispersion and time discretezation have been thoroughly addressed by discussing Peclet and Courant numbers characteristic of the flow and fate and transport models.

Figure 30: The decrease in PCE concentration at well TT-26 is caused by the onset of pumping at 4 new supply wells, three of which are directly south of ABC One-Hour Cleaners and well TT-26. Close examination of Figure 30 would indicate that the concentration decrease actually began in early 1962 following the onset of simulated pumping at these well in January 1962. This additional pumping diverted some PCE mass from a previous entirely southeasterly direction to a more southerly direction away from well TT-26.

p. 70, Sensitivity Analysis: No comment

p. 70, Sensitivity Analysis: The discussion of sensitivity analyses is incomplete, as the reviewer has implied in his comments. Sensitivity analyses in the modified report is based on an RMS computation of observed PCE concentrations at the Tarawa Terrace WTP and supply wells. A total of 29 paired data were available to compute the RMS for sensitivity determination.

For the record, the longitudinal dispersivity was only changed by a factor of 10, maximum.

p. 71 & Table 7: Agree. Table 7 will be modified to include the key to reading sample depth. As a common practice, the sample depth is imbedded in the site designation. For example at site 5, the site names HC-5-25 and HC-5-40.5 indicate samples at site 5 collected at depths of 20 feet and 40.5 feet.

p. 71-72, sample anomalies: The reviewer's comments are confusing. Sampling methodologies using a hydrocone seldom deviate from site to site with depth. A hydocone point is pushed to a particular depth, a small window is opened at the exterior of the cone, a tiny sample of pore water is obtained and stored in a vile in the cone, and a few cubic inches of aquifer is sampled. Such techniques are applied over and over with little variation. The reviewer is incorrect in stating that the authors did not consider laboratory error as a possible reason for widely different analytical results. A discussion of possible errors related to a "CLP" and a mobile lab comprises a major part of information presented on page 71.

The discussion of possible analytical errors on page 72 refers only to supply wells, not hydrocone samples. Samples collected at such wells are composite samples obtained through dozens of feet of open interval. Obviously, concentration gradients over the open interval would not be evident because of mixing.

p. 74-75: Agree. A sensitivity analysis was accomplished per the reviewer's suggestion. The sensitivity of simulated concentrations to time discretization was tested by assigning one-day stress periods to the calibrated fate and transport model for the period November 1, 1984 to January 31, 1985 and comparing the concentrations simulated by the modified model to those of the calibrated model. Comparisons were made for the days November 30, 1984, December 31, 1984, and January 31, 1984. Pumpage assigned to the months of interest of the calibrated model was assigned to every day of the respective month of the modified model. Field data and the calibrated model indicated that supply wells TT-23 and TT-26 were substantially contaminated with PCE during the test period. Also, concentration gradients simulated by the calibrated model were large in the vicinity of wells TT-23 and TT-26 at this time. Concentrations simulated by the calibrated and modified models were identical prior to stress period 407 (November 1984). The PCE concentrations simulated by the modified and calibrated models during the test period at wells TT-23 and TT-26 are listed in the following table. Simulated concentrations at supply wells TT-23 and TT-26 were similar to the third or fourth significant figure at the designated times whether or not the stress period length was 1 day or 30 days or 31 days. Thus PCE concentrations simulated by the Tarawa Terrace fate and transport model were demonstrably unaffected by numerical instabilities caused by inappropriate time discretization.

Site Name	Simulated Elapsed Time, in days	Date	$\Delta t = 1$ day Simulated PCE Concentration, in grams/ft^3	$\Delta t = 30$ or 31 days Simulated PCE Concentration, in grams/ft^3
TT-23	12,388	Nov. 30, 1984	0.007183956	0.007182317
	12,419	Dec. 31, 1984	0.007214860	0.007211736
	12,450	Jan. 31, 1985	0.007200035	0.007198663
TT-26	12,388	Nov. 30, 1984	0.02297354	0.02298510
	12,419	Dec. 31, 1984	0.02276520	0.02279888
	12,450	Jan. 31, 1985	0.02275406	0.02276190